

Short Abstract - *Analysis of Separation Corridors for Visiting Vehicles from the International Space Station*

Separations from the International Space Station (ISS) have many operational constraints that place limits on ISS operations. In particular, Solar Array (SA) positioning limits are utilized which reduce ISS operational flexibility in order to prevent collisions during Russian Vehicle (RV) separations. The purpose of this paper is to discuss the analysis that was applied to relax these SA constraints while ensuring safe relative separations. The analysis applied numerical propagation of the relative motion and attitude dynamics to generate a set of separation trajectories. These trajectories were then used to define the safe separation corridors for RV undockings and thereby relax the previous SA constraints.

Extended Abstract

Analysis of Separation Corridors for Visiting Vehicles from the International Space Station

MARIUSZ P. ZACZEK, RITA R. SCHROCK, MARK B. SCHROCK, BRYAN C. LOWMAN

Automated Rendezvous and Docking - Visiting Vehicle Office

NASA/Johnson Space Center

2101 NASA Parkway

Houston, TX 77058

The International Space Station (ISS) is a very dynamic vehicle with many operational constraints that affect its performance, operations, and vehicle lifetime. Most constraints are designed to alleviate various safety concerns that are a result of dynamic activities between the ISS and various Visiting Vehicles (VVs). One such constraint that has been in place for Russian Vehicle (RV) operations is the limitation placed on Solar Array (SA) positioning in order to prevent collisions during separation and subsequent relative motion of VVs. An unintended consequence of the SA constraint has been the impacts to the operational flexibility of the ISS resulting from the reduced power generation capability as well as from a reduction in the operational lifetime of various SA components. The purpose of this paper is to discuss the technique and the analysis that were applied in order to relax the SA constraints for RV undockings, thereby improving both the ISS operational flexibility and extending its lifetime for many years to come.

This analysis focused on the effects of the dynamic motion that occur both prior to and following RV separations. The analysis involved a parametric approach in the conservative application of various initial conditions and assumptions. These included the use of the worst case minimum and maximum vehicle configurations, worst case initial attitudes and attitude rates, and the worst case docking port separation dynamics. Separations were calculated for multiple ISS docking ports, at varied deviations from the nominal undocking attitudes and included the use of two separate attitude control schemes: continuous free-drift and a post separation attitude hold. The analysis required numerical propagation

of both the separation motion and the vehicle attitudes using 3-degree-of-freedom (DOF) relative motion equations coupled with rigid body rotational dynamics to generate a large set of separation trajectories.

The result of the analysis was the generation of multiple trajectory profiles emanating from each of the analyzed docking ports. Since each trajectory represents the center of mass path of the separating vehicles, additional bounding volumes representing the vehicles were superimposed at these positions in order to limit their structural extents (as seen in the figure below).

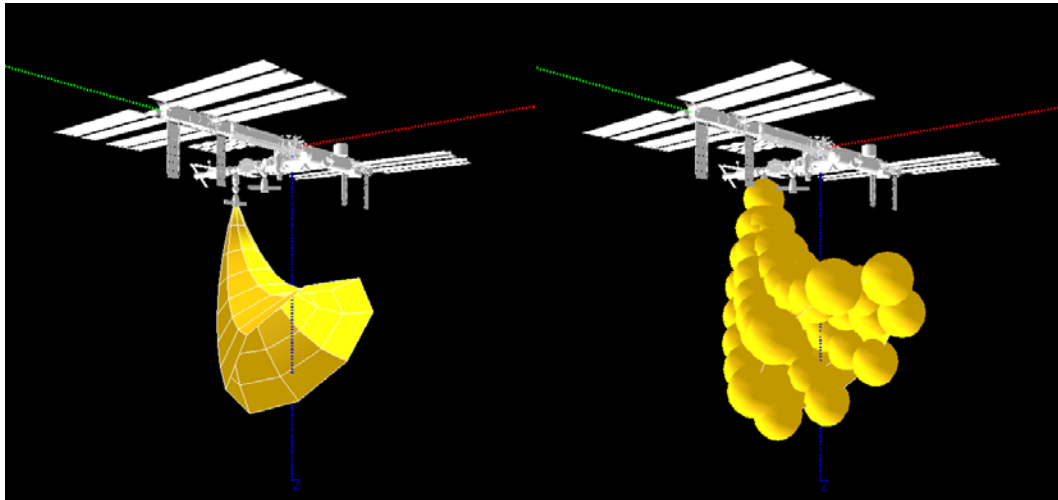


Figure 1: (left) Set of separation trajectories. (right) Structural bounding volumes applied to the separation trajectories.

The individual bounding volumes were then combined to generate the bounding corridors from each docking port (as seen in the figure below) and represent worst case structural limits of a separating vehicle relative to the rotating ISS body.

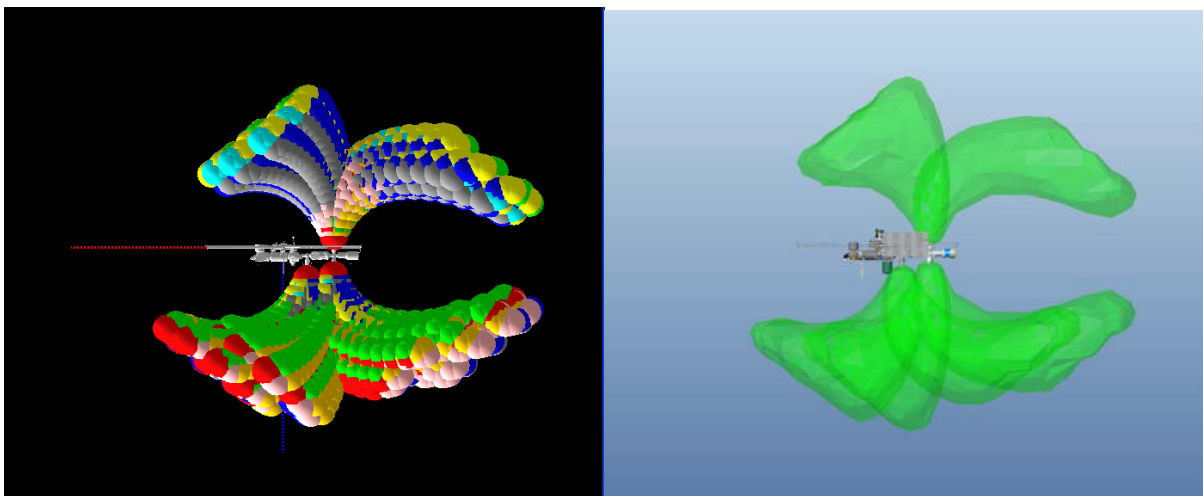


Figure 2: (left) Structural bounding volumes for each separation trajectory. (right) Bounding corridors.

As a result of this analysis, it was determined that certain scenarios provided safe clearance and separation for the undocking vehicles while allowing for the relaxation of various ISS constraints including the aforementioned SA constraints. The results have led to the building of new RV and ISS undock timeline procedures in order to protect SAs and RVs from post separation damage, and have allowed for the creation of updated ISS Ku-band masks to use for departing and approaching RVs. The resulting relaxation of constraints has not only increased the operational flexibility of the ISS but also reduced both the operational and analysis costs for future RV separations.